DOCUMENT RESUME

ED 196 860 SP 017 078

AUTHOR Tobin, Kenneth G.; Capie, William
TITLE The Effects of Teacher Wait-Time and Questioning Quality on Middle School Science Achievement.
PUB DATE Sep 80
NOTE 35p.; Paper presented at the Annual Meeting of the American Psychological Association (Montreal, Canada, September, 1980).

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Abstract Reasoning; Academic Achievement; Attention Control; *Attention Span; Curriculum Development; Discussion (Teaching Technique); Educational Objectives; Feedback; Inquiry; Junior High Schools; *Questioning Techniques; Science Instruction; Student Reaction; *Time Factors (Learning)

ABSTRACT

An experiment was conducted on the effects of two teacher variables and student engagement on science achievement. The variables included: teacher wait-time, defined as the length of the pause preceding a teacher utterance; and questioning quality, a generic term used to describe cognitive level, clarity, and relevance of questioning. Thirteen middle school teachers were randomly assigned to four groups to receive feedback on: wait-time and questioning quality; wait-time only; questioning quality only; and placebo feedback only. The feedback was designed to increase teacher wait-time beyond three seconds and to increase the quality of teacher questioning. Twelve students were selected from each class in order to estimate rates on nine different categories of engagement. Measures of formal reasoning ability and locus of control were obtained for all students in the study. Variation in science achievement was significantly related to variation in teacher wait-time, formal reasoning ability, and two categories of student engagement (attending and generalizing). The results indicated that achievement may be increased by using a mean teacher wait-time of approximately three seconds and ensuring that students are maximally engaged on the instructional objectives. (Author/JN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED196860

The Effects of Teacher Wait-Time and Questioning Quality on Middle School Science Achievement

Kenneth G. Tobin
William Capie

University of Georgia
212 Aderhold Hall
Department of Science Education
Athens, Georgia 30602

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Kenneth Tobin

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

A paper presented at the annual meeting of the American Psychological Association, Montreal, September, 1980.

SP 017 028

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

THE EFFECTS OF TEACHER WAIT-TIME AND QUESTIONING QUALITY OF MIDDLE SCHOOL SCIENCE ACHIEVEMENT

Modern science curricula are characterized by a balance of concept and process objectives. The integrated science processes are a set of intellectual skills related to planning and conducting an investigation. Skills such as defining operationally, interpreting data, formulating hypotheses, controlling variables and experimenting are often advocated as a component of a middle school curriculum. Despite the availability of process oriented curriculum materials, such as Science - A Process Approach (1967, 1975), process skills do not appear to be widely taught, and little research has been directed toward identifying teaching strategies that are related to integrated process skill achievement.

The use of questions to provide a cognitive focus on the instructional objectives represents a possible means of increasing process skill achievement. Questions that are relevant to the objectives, clearly stated and require students to engage at the cognitive level of the objectives, should facilitate learning. Since integrated process skills objectives represent higher cognitive skills, achievement should be positively related with the cognitive level of questioning. However, merely increasing the level of the activity may not be sufficient to increase achievement. If the purpose of a question is to promote engagement on a higher level objective, then adequate time should be provided for students to formulate an appropriate response. Rowe (1974) reported positive changes on teacher and student verbal behaviors when wait-time, the pauses immediately preceding and following teacher questions, exceeded three seconds. Tobin (1980) manipulated the length of the pause preceding

teacher talk and found that as the average length of the pauses increased, science achievement increased. Thus, by extending the length of the pauses that precede teacher talk, student achievement on integrated process skills also may be increased.

A number of studies have indicated a strong relationship between forman reasoning ability and science achievement (e.g., Raven and Polanski, 1974; Cantu and Herron, 1978). The research indicates that students who are able to utilize formal thought operations are able to solve problems and form concepts that are beyond the capabilities of those who do not possess formal modes of reasoning. Although there are obvious direct logical links between formal thought and integrated processes such as controlling variables and hypothesizing (Wood, 1974), few attempts have been made to empirically validate the relationship. On the basis of the logical relationship, however, students with high formal reasoning ability should achieve at a higher level on process skill outcomes than those with low formal reasoning ability.

Locus of control is a variable that relates to an individual's tendency to accept responsibility for success or failure. Students with an internal locus of control tend to make greater use of information and are more likely to engage in data gathering than students with an external locus of control (Davis and Phares, 1967). Prior studies have shown that students with an internal locus of control achieve at a higher level than students with an external locus of control (e.g., Saunders and Yeany, 1979). Thus, internal students may strive to succeed on higher cognitive objectives to a greater extent than students who perceive success as being related to factors beyond their control.

In addition to formal reasoning ability and locus of control, the quantity and quality of student engagement during science lessons is likely

to influence process skill outcomes. Students who are engaged in behaviors that are closely related to the instructional objectives may achieve at a higher level than students who are not engaged in this way.

Purpose

The purpose of this study was to investigate teacher and student variables that are likely to influence process skill learning. The research questions are referenced to the model in Figure 1 which shows how teacher behavior, learner attributes and rates of academic engagement might influence integrated process skill achievement.

(Include Figure 1 About Here)

Five research questions were formulated as a basis for the study. The questions are related to components II, III, VI and VII of the model in Figure 1.

1. How is variation in teacher wait-time related to science process achievement? (I)
2. How are variations in questioning relevance, questioning clarity and the cognitive level of questioning related to science process achievement? (I)
3. How is variation in student engagement related to science process achievement? (II)
4. How is variation in student formal reasoning ability related to science process achievement? (VI)
5. How is variation in student locus of control related to science process achievement? (VII)

Rationale

The use of an increased teacher wait-time should provide students with additional time to think about problems that have been posed or procedures to be followed. Prior research has shown that the use of an increased wait-time teaching style resulted in improved student verbal

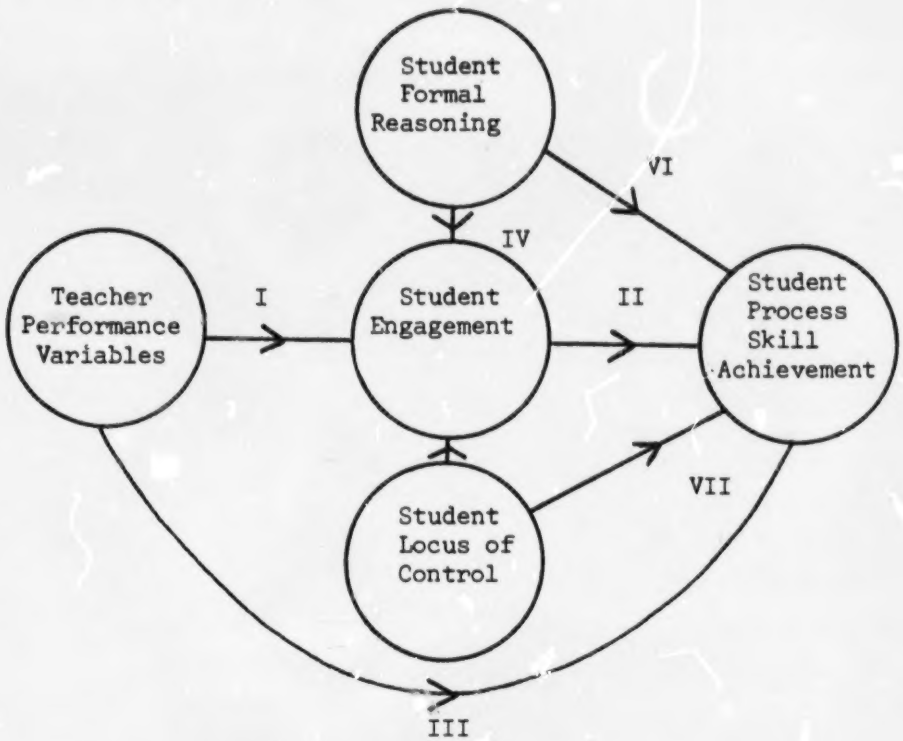

Figure 1. A process-product model for student achievement of science processes.

behaviors (Rowe, 1974; Lake, 1973) and increased science achievement (Tobin, 1980; Riley, 1980). Thus, the use of an extended teacher wait-time, particularly in conjunction with higher cognitive questions, should enhance process skill achievement.

While all students are expected to benefit from increased wait-time, students with higher formal reasoning ability may use additional time to formulate appropriate responses and learn. Because of limitations in ability to think abstractly, students with lower levels of formal reasoning ability may have difficulty in using the time productively, particularly if higher level questions are asked.

Saunders and Yeany (1979) reported that students with internal locus of control attained higher summative achievement and retention scores than students with an external locus of control. Other research (e.g., Rotter and Mulry, 1965) has indicated that students with an internal locus of control spend more time deliberating about decisions and consequently take more time to arrive at a decision than students with an external locus of control. Julian and Katz (1968) reported that internals took more time to make decisions as task difficulty increased. Irrespective of task difficulty, externals used approximately the same time to arrive at a decision. Thus, as the cognitive level of questioning increases, internals should require additional time to arrive at a decision. The use of higher cognitive questions in conjunction with an extended teacher wait-time should therefore provide an optimal learning environment for internal students.

A number of investigations have related academic engagement with achievement. For example, Ladaherne (1968) reported correlations ranging from .37 to .53 for attending behavior and achievement on the Stanford Achievement test. In a similar study Cobb (1972) reported correlations from

.40 to .48 for attending behavior with achievement on the Stanford Mathematics test. Thus, academic engagement was also expected to influence process skill achievement. As well as attending, which is a covert type of engagement, overt categories of engagement such as identifying variables, graphing data and hypothesizing were expected to be related to achievement.

Procedures

Thirteen classes from four middle schools in Clarke County, Georgia were selected to participate in the study. Five of the selected classes were from grade eight, four from grade seven and four from grade six.

The classes participating in the study were heterogeneous with respect to socioeconomic status, race and intelligence. The range on each of these variables within each class was similar for all participant classes in accordance with a policy of hetergeneous grouping that was adopted in the school district. Sixty percent of the sample were white, thirty-seven percent black and three percent were of other races.

Within each grade level, one class was assigned to one of four feedback groups defined on the basis of manipulation of questioning quality and/or teacher wait-time. The four groups were:

1. extended teacher wait-time; high questioning quality;
2. extended teacher wait-time; normal quality of questioning;
3. normal teacher wait-time; high quality of questioning; and
4. normal teacher wait-time; normal quality of questioning.

In grade eight, where five classes were involved, two classes were randomly assigned to group one.

Extended Teacher Wait-Time

Teachers in the extended wait-time groups were asked to maintain a mean wait-time between three and five seconds. After each lesson, the teachers in group one and group two received feedback on their mean teacher

wait-time. The feedback was presented and discussed prior to each lesson with a view to maintaining an extended wait-time.

Quality of Questioning

Teachers in the quality of questioning groups were asked to maintain a high level on three questioning variables: cognitive level, clarity and relevance. Written information was provided on the nature of each variable and after the first lesson, specific feedback was provided on the questions asked in the previous lesson. The feedback was presented and discussed prior to each lesson with a view to improving or maintaining questioning quality.

Placebo Feedback

So that all teachers in the study received feedback and consultation, a placebo feedback was administered. Teachers in group four received suggestions on what was to be taught prior to each lesson. Discussion usually focused on lesson plans or use of materials. The questioning variables and teacher wait-time were not discussed with teachers in this group.

Research Design

The research design may be represented using Campbell and Stanley (1966) notation in the following manner.

O_1 O_2 X_1 O_6 X_5 O_7
($O_3O_4O_5$)

- - - - - - - - - - - - - - - -

O_1 O_2 X_2 O_6 X_5 O_7
($O_3O_4O_5$)

- - - - - - - - - - - - - - - -

O_1 O_2 X_3 O_6 X_5 O_7
($O_3O_4O_5$)

- - - - - - - - - - - - - - - -

O_1 O_2 X_4 O_6 X_5 O_7
($O_3O_4O_5$)

- - - - - - - - - - - - - - - -

The symbols used in the above diagram represent the following measures and treatments.

O_1 = premeasure of locus of control;

O_2 = premeasure of formal reasoning;

X_1 = extended wait-time; high quality of questioning;

X_2 = extended wait-time; normal quality of questioning;

X_3 = normal wait-time; high quality of questioning;

X_4 = normal wait-time; normal quality of questioning;

O_3 = student engagement measures;

O_4 = teacher wait-time measures;

O_5 = quality of questioning measures;

O_6 = summative achievement measure;

O_7 = retention measure.

A sequence of eight science lessons was presented in each class over a two week period of time. Each lesson was developed from a learning hierarchy to promote the acquisition of twelve objectives related to hypothesizing, interpreting data, identifying and controlling variables, and defining operationally. The algorithm used to develop the lessons for the study is fully described elsewhere (Tobin and Capie, 1980a).

Teacher behaviors and student engagement were not measured in the four week interval between the administration of the summative achievement and retention measures. During this period of time all classes were involved in lessons that emphasized science content rather than science processes. The specific content of these lessons varied with grade level. The emphasis given to processes between test occasions was not known; however, systematic covariation with respect to the various independent and dependent variables was unlikely.

Selection of Subjects

A quasi-random sampling procedure was used to select twelve students from each class as data sources for categories of academic engagement. Prior research (cf., Chiappetta, 1976), suggested that only a small percentage of students would obtain high formal reasoning scores. To satisfactorily investigate the research questions, however, a broad range of formal reasoning ability was required in the sample to be observed. Within each class, four students were randomly selected from those scoring greater than three on the Test of Logical Thinking (TOLT) (Tobin and Capie, 1980b), four students from those scoring two or three, and four students from those scoring less than two. The stratifying procedure was adopted to assure that a satisfactory range of formal reasoning ability was represented in the sample. The scores used for stratification were selected on the basis of prior performance on TOLT (see Tobin and Capie, 1980b). In classes where less than four students were represented in the highest category, additional students were selected from those scoring two or three on TOLT.

Since formal reasoning ability and locus of control are uncorrelated (Tobin and Capie, 1979) this sampling procedure did not systematically influence the locus of control data represented in the sample.

Data Analysis

The effectiveness of the feedback procedures was assessed using discriminant analysis with feedback group as a classification variable and wait-time, questioning relevance, questioning clarity and cognitive level of questioning as dependent variables. The purpose of this analysis was to determine whether the feedback procedures produced discernible differences between groups on the four variables. Thus, the percentage of agreement between feedback group membership and predicted group membership based on measures on the four manipulated variables is an indication of the extent to which the variables were successfully manipulated.

Continuous measures on all teacher and student variables were used in data analyses. Descriptive statistics were calculated for all variables and the relationships of manipulated variables and student attribute measures with process skill achievement were investigated with product moment correlations.

Research questions involving the manipulated variables were investigated at the class and individual student levels. Analyses based on class means were conducted to provide an indication of the general effectiveness of the manipulated variables. The results of these analyses are generalizable to other middle school classes and teachers. However, since the research questions were concerned with attributes of individuals generalization to individuals with similar attributes was also desirable. As a consequence, additional analyses based on individual measures as units of analysis were also conducted. The possible effects of statistical violations due to dependence of data from individuals in the same class were minimized through the use of random procedures whenever possible. Teachers were randomly assigned to feedback groups, students were randomly selected to be sources for engagement data and the order in which individual engagement data were gathered was randomly determined.

Separate univariate analyses were conducted on summative achievement and retention to determine the relative effects of the manipulated variables, formal reasoning, locus of control and rates of attending and generalizing. Attending and generalizing rates were incorporated in these analyses because they were significantly correlated with process skill achievement. Multiple regression analyses were used to investigate the research questions.

Variables

This section contains operational definitions for each of the variables measured in the study.

Quality of questioning and wait-time were measured from audio-tapes, and student engagement was rated by direct observation of each lesson. Each of the above variables was measured by the same person.

The quality of questioning variables were assessed for each teacher on the basis of a sample of thirty questions randomly selected from audio-tapes of each lesson. The mean for each teacher was based on the grand mean over all questions and all lessons. Generalizability coefficients (Cronbach, Gleser, Nanda and Rajaratnam, 1972) for the measures obtained indicated that the data were dependable for differentiating teacher questioning quality and generalizing over questions and lessons. The coefficients obtained were: clarity, .91; relevance, .89; and, cognitive level, .87.

Cognitive Level of Questioning. The categories of engagement from Transactions in Science (TIS) (Table 1) were used to code each question according to the behavior it was intended to elicit. A weight (Table 1) which reflected the position of the TIS category on a cognitive hierarchy was assigned to each question. An index, representing the cognitive level

of questioning, was calculated as the mean over the sampled questions and all lessons.

(Include Table 1 About Here)

Questioning Clarity. A clear question communicates precisely what is required of the learner. To the extent that lack of precision contributes to misunderstanding, a question was considered unclear. The presence of one or more of the following indicators suggested a lack of clarity.

1. Words that are difficult to understand were used in the question.
2. Excessive vocabulary was contained in the question.
3. Multiple questions were posed.
4. Complex sentence structure was evident in the question.
5. Tangles of words were present in the question.
6. Qualifiers were used in the question (e.g., almost, pretty much, quite a bit, possibly, etc.).
7. One or more false starts occurred when the question was posed.
8. Halts in speech disrupted the flow of the question.
9. Redundant information was contained in the question.

Each question was assigned a clarity rating using the following guidelines in conjunction with the nine indicator statements.

1. A rating of two was assigned to clearly stated questions.
2. A rating of one was assigned when the presence of one or more indicators contributed to slight impr[illegible]sion. In this case there was no evidence of misunderstanding attributable to lack of clarity of the question.
3. A rating of zero was assigned when the presence of one or more indicators resulted in unclear presentation of the question.

An index, representing questioning clarity, was calculated as the mean over the sample of questions and all of the lessons.

Questioning Relevance. Relevance was defined in terms of the timeliness of the question and the match between the purpose of the question and the lesson objectives.

Untimely questions were characterized in the following way:

1. The question should have been asked at an earlier time in the lesson.
2. The question should have been asked at a later time in the lesson.
3. The question was repeated when it was not necessary to do so.
4. The question resulted in an undesirable change in the lesson.
5. The question interrupted another speaker.

Each question was assigned a relevance rating using the following guidelines.

1. A rating of two was assigned when: (a) there was a high level of concurrence between the purpose of the question and the instructional objectives; and, (b) the question was asked at an appropriate time.
2. If the question was asked at an inappropriate time, a rating of one or zero was assigned. Irrespective of timelines, a rating of zero was made when there was little concurrence of the purpose of the question and the objectives.

An index representing questioning relevance was calculated as the mean over the sample of questions and all of the lessons.

Teacher Wait-Time. Wait-time was defined as the length of the pause preceding any teacher utterance. Figure 2 shows that teacher or student talk can precede the relevant pause.

(Include Figure 2 About Here)

As defined in this study, wait-time embraced all utterances that occurred in an instructional sequence. The following situations were relevant to the measurement of teacher wait-time:

1. When child dialogue was followed by a teacher utterance.
2. When a teacher utterance was followed by another teacher utterance.

Discourse that was extraneous to the lesson objectives, such as discipline or classroom organization moves, was not considered in the analysis. Wait-time was measured from audiotapes of the lessons with an accuracy of one-tenth of a second using a servo-chart recorder (see Tobin, 1980).

Wait-time measuring points were randomly sampled from each audiotape such that thirty wait-time measures were sampled throughout each lesson. The arithmetic mean of the relevant pauses was computed for each teacher for each lesson.

A generalizability coefficient of .96 was obtained for the wait-time measures used in the study.

Academic Engagement

In this study the behavior of each student was observed for one lesson of every two using a time sampling procedure in which behavior was observed for four seconds during each 30 second interval. If more than one codable behavior occurred in the four second interval, the predominant behavior to occur in that interval was recorded. The order in which students were observed was randomly determined.

Frequency counts constituted the raw data for the analysis. To enable proportions to be caluclated for each engagement category, behavior data for each student were pooled over the four lessons that were rated. The proportion of time allocated to each mode of engagement for each student was used as the unit for analysis for hypotheses related to student engagement. A generalizability coefficient for differentiating students and generalizing over lessons was estimated for each engagement category (Table 2).

(Include Table 2 About Here)

Formal Reasoning Ability. Formal reasoning ability of students was measured with a multiple response, paper and pencil test developed for this study (Tobin and Capie, 1980b). The Test of Logical Thinking (TOLT) consists of ten items which provide a measure of formal reasoning on five dimensions; proportional reasoning, controlling variables, combinatorial reasoning, probabilistic reasoning and correlational reasoning. Two items for each mode of thinking are contained in the test. The internal consistency reliability for TOLT was .85.

Locus of Control. The Intellectual Achievement Responsibility (IAR) scale (Crandall, Katkovsky and Crandall, 1965) was used to obtain a measure of locus of control. The internal consistency reliability of the test was .66.

Integrated Science Processes. Integrated science process achievement was measured on two occasions with a 24 item, criterion-referenced test (Tobin and Capie, 1980c). The pencil and paper, multiple response test, consisted of two items for each of 12 instructional objectives related to the integrated science processes. The internal consistency reliability of the test was .81.

Results

The data analyses are contained in three sections below: Effectiveness of feedback: Descriptive data; and, Multiple regression analyses.

Effectiveness of Feedback

Feedback group means for teacher wait-time and the quality of questioning variables are contained in Table 3. The discriminant analysis data indicated that for 12 of 13 teachers the feedback groups to which

they were randomly assigned coincided with groups formed on the basis of measures of wait-time and questioning quality. The data in Table 4 indicate that one teacher from the quality of questioning feedback group was misclassified. This teacher's profile of wait-time and questioning data more closely resembled that of a teacher from the placebo feedback group.

(Include Table 3 and Table 4 About Here)

Descriptive Data

Means and standard deviations are provided for each variable in Table 5. The correlations in Table 6 show formal reasoning ability, generalizing, attending and teacher wait-time to be the strongest predictors of integrated science process skill achievement.

(Include Table 5 and Table 6 About Here)

Multiple Regression Analyses

The data in Table 7 show that formal reasoning ability accounted for 26 percent of the variance in summative achievement when individual measures were used as the unit for analysis. Teacher wait-time was significantly related to summative achievement, although the proportion of variance attributable to each in the presence of the other variables was small.

(Include Table 7 About Here)

The results for the retention measure were similar to those obtained for summative achievement. Formal reasoning ability was strongly related to retention, accounting for 38 percent of the variation in the retention measure. Teacher wait-time was also significantly related to retention, accounting for three percent of the variance. The rate of student generalizing was significantly related to retention, accounting for five percent of the variance. Student attending was not significantly related

to retention in the presence of the other variables.

The analysis based on class means confirmed the importance of the relationships of formal reasoning, attending and teacher wait-time to summative achievement (see Table 8). A statistically significant proportion of the variance in summative achievement was also attributable to locus of control. The comparative magnitude of the effect due to locus of control was small, however, and the result may have little practical significance.

(Include Table 9 About Here)

Analysis of the retention data indicated that 76 percent of the variance was attributable to formal reasoning and teacher wait-time. Thus, when between class differences in formal reasoning were considered, the use of an extended wait-time during the initial teaching sequence was associated with higher retention scores. Multiple regression analysis indicated the presence of a statistically significant interaction between teacher wait-time and the cognitive level of questioning. These results should be interpreted with extreme caution, however, as the estimated variance attributable to the interaction was on the order of two percent in each analysis. Neither the interaction nor the cognitive level of questioning was statistically significant when class means were used as the unit for statistical analysis.

The effects of other variables and interactions on achievement were also tested. Although statistically significant models were found involving summative achievement and: (1) cognitive level of questioning and locus of control; and, (2) questioning clarity and locus of control; the total models accounted for only two percent and five percent of the variance in summative achievement respectively. Since these data have no practical importance they are not reported.

Discussion

The data from Table 3 and Table 4 suggest that the feedback procedures were effective in manipulating teacher wait-time and the quality of questioning variables. Since teachers were randomly assigned to feedback groups, variations that occurred in the dependent variables of interest may be attributed to variations in teacher wait-time and questioning quality. An indication of the effectiveness of the feedback in modifying teacher behavior was the high proportion of teachers whose group membership was confirmed by discriminant analysis together with the group means reported in Table 3. Although many teachers in non-feedback groups asked questions that were relevant, clear and at a high cognitive level, the group means for feedback groups were greater than the means of non-feedback groups on each questioning variable. The relatively small standard deviations associated with feedback groups on each questioning variable are also of interest. The consistent feedback apparently reduced the variation between teachers.

Higher wait-time means were tained by the wait-time feedback groups than non-feedback groups. Wait-time was an easier variable to manipulate. The highest teacher wait-time from a non-feedback group was below the lowest teacher wait-time for a wait-time feedback group.

The misclassified teacher was from the high quality of questioning questioning feedback group. Feedback on questioning was unable to increase this teacher's questioning quality to a level that was comparable with others in the high quality of questioning group.

This result had no implications for data analysis since continuous measures were used on each questioning variable rather than categorical measures based on feedback group membership.

The relationship of formal reasoning ability with process skill achievement was highlighted by the large proportion of variance in achievement attributable to formal reasoning. The importance of teacher wait-time to process skill learning was also clear from each of the analyses. This result was consistent with earlier research reported by Tobin (1980) where the use of an increased wait-time increased achievement on science content outcomes.

In the short term, student formal reasoning ability is unlikely to change appreciably. Thus, low formal reasoning ability will limit achievement of middle school students. However, the results obtained indicate that teachers might increase integrated process skill achievement by increasing teacher wait-time, and student engagement on the attending and generalizing categories. A question that needs further investigation is whether other categories of engagement are also important determinants of process skill achievement. For example, if students were overtly engaged in planning rather than covertly engaged through the attending mode, achievement might be enhanced. Similarly, comprehending may also be related to process skill achievement. The relative improtance of covert versus overt engagement on categories of engagement is an area for further research.

The results suggest that the effects of variation in locus of control on achievement and retention appear to be negligible. An alternative explanation is that unreliability of the locus of control measure and the resultant lack of power attenuates the magnitude of the true relationship that exists. Support for this explanation is obtained from multiple

regression analysis using class means, which are more reliable than individual measures. Although the magnitude of the effect of locus of control on summative achievement was small, the date in Table 8 indicate a small positive relationship with achievement. Further research using more reliable measures of locus of control is warranted.

Although questioning clarity and relevance were manipulated in the study, the variables did not have a direct effect on summative achievement or retention. The questioning clarity data were reliable; however, the entire range (from 1.48 to 1.98) represents clear questioning. To adequately investigate the effects of questioning clarity, manipulation would be needed to ensure that some teachers asked predominantly unclear questions. A similar explanation is offered for the lack of a significant relationship between questioning relevance and achievement.

Data from multiple regression analyses suggested an optimal mix of high and low level questions corresponding to an index of approximately 2.1. The effects of variation in cognitive level of questioning on achievement were not strong; however, a trend suggested that a mix of questions at varying cognitive levels resulted in the highest achievement levels. The proportion of high and low level questions that is optimal is a variable that is probably dependent on attributes of the learner and the cognitive level of the instructional objectives.

The use of questioning as a basic unit for classroom research should be reconsidered. The model proposed in Figure 1 highlights the importance of the teacher's ability to promote student engagement. Thus, a more appropriate unit for research would be solicitation, which would include all verbal behaviors that were intended to provide a cognitive focus. Thus, the effectiveness of teacher directions, which are commonly used to establish a cognitive focus, could be investigated along with questions.

Questions that were not intended to provide a cognitive focus would be excluded from the solicitation category.

Conclusion

The data reported in this study were collected following eight lessons which emphasized the objectives that were assessed. On the basis of the data obtained, the logical relationship between formal reasoning ability and integrated process skill achievement was empirically confirmed. Integrated process skill achievement and retention were each related to student formal reasoning ability. From a teaching viewpoint, the data indicated that achievement gains were possible by using a mean teacher wait-time of approximately three seconds and ensuring that students are maximally engaged on the instructional objectives.

REFERENCES

American Association for the Advancement of Science. Science--A Process Approach. Lexington, MA: Ginn, 1967, 1975.

Campbell, D. T., & Stanley, J. C. Experimental and quasi-experimental designs for research. Chicago: Rand McNally College Publishing Co., 1966.

Cantu, L., & Herron, D. Concrete and formal Piagetian stages and science concept attainment. Journal of Research in Science Teaching, 1978, 15, 135-143.

Chiappetta, E. A review of Piagetian studies relevant to science instruction at the secondary and college level. Science Education, 1976, 60, 253-261.

Cobb, J. A. Relationship of discrete classroom behaviors to fourth-grade academic achievement. Journal of Educational Psychology, 1972, 63, 74-80.

Crandall, V. V., Katkovosky, W., & Crandall, V. J. Children's beliefs in their own control of reinforcements in intellectual-academic situations. Child Development, 1965, 36, 91-109.

Cronbrach, L. J., Gleser, G.C., Nanda, H., & Rajaratnam, N. The dependability of behavioral measurements: Theory of generalizability for scores and profiles. New York: Wiley, 1972.

Davis, W. L., & Phares, E. J. Internal-external control as a determinant of information-seeking in a social influence situation. Journal of Personality, 1967, 35, 547-561.

Julian, J. W., & Katz, S. B. Internal versus external control and the value of reinforcement. Journal of Personality and Social Psychology, 1968, 76, 43-48.

Ladaherne, H. M. Attitudinal and intellectual correlates of attention: A study of four sixth-grade classrooms. Journal of Educational Psychology, 1968, 59, 320-324.

Lake, J. H. The influence of wait-time on the verbal dimension of student inquiry behavior. (Doctoral dissertation, Rutgers University, 1973.) Dissertation Abstracts International, 1974, 34, 6476-A. (University Microfilms No. 74-08, 866).

McGhee, P. E., & Crandall, V. C. Beliefs in internal-external control of reinforcement and academic performance. Child Development, 1968, 39, 91-102.

Raven, R., & Polanski, H. Relationships among Piaget's logical operations, science content comprehension, critical thinking and creativity. Science Education, 1974, 58, 531-544

Riley, J. P. II. The effects of teachers' wait-time and cognitive questioning level on pupil science achievement. Journal of Research in Science Teaching, 1980, 17, (in press).

Rotter, J. B., & Mulry, R. C. Internal versus external control of reinforcements and decision time. Journal of Personality and Social Psychology, 1965, 2, 598-604.

Rowe, M. B. Relation of wait-time and rewards to the development of language, logic and fate control: Part one--wait-time. Journal of Research in Science Teaching, 1974, 11, 263-279.

Saunders, R. L., & Yeany, R. H. The effects of diagnosis, remediation and locus of control on achievement retention, and attitudes of middle school science students. A paper presented at the annual meeting of the National Association for Research in Science Teaching, Atlanta, March, 1979. (ERIC Document Reproduction service No. ED 174-404).

Tobin, K. G. The effect of an extended wait-time on science achievement. Journal of Research in Science Teaching, 1980, 17, (in press).

Tobin, K. G., & Capie, W. The relationship of formal reasoning ability and locus of control. A paper presented at the annual meeting of the Southeastern Association for the Education of Teaching of Science, Alabama, October, 1979. (ERIC Document Reproduction Service No. ED 179 386).

Tobin, K. G., & Capie, W. Teaching process skills in the middle school. School Science and Mathematics, 1980a, (in press).

Tobin, K. G., & Capie, W. The development and validation of a group test of logical thinking. A paper presented at the annual meeting of the American Education Research Association, Boston, April, 1980b (ERIC Document Reproduction Service NO.).*

Tobin, K. G., & Capie, W. Development and validation of a group test of integrated science processes. Journal of Research in Science Teaching, 1980c, (Paper submitted for publication).

Winne, P. H. Experiments relating teachers' use of higher cognitive questions to student achievement. Review of Educational Research, Winter 1979, 49, 13-50.

Wood, D. A. The Piaget-process matrix. School Science and Mathematics, 1974, 74, 407-412.

* ED number not yet allocated. The paper is also submitted for publication to Educational and Psychological Measurement.

Table 1

Definitions and Cognitive Weights for Transactions in Science

Category	Definition	Cognitive Weight
1. Attending	Looking at the teacher, book, worksheet, paper, chalkboard, etc. Physically attending to a task.	-
2. Recalling	Responding to questions with recalled facts. Stating definitions. Stating names and/or terms without explaining their meaning. Stating matters of fact.	1
3. Collecting	Collecting data in an investigation. Copying material from books or the chalkboard, etc. Recording data in an investigation.	1
4. Comprehending	Explaining the meaning of a term. Naming data points on a graph. Describing graphic or tabular data. Reporting techniques. Reporting data. Representing data in a different mode.	2
5. Quantifying	Calculating relations between data. Reducing many bits of data to a representative value. Determining a scale for graphic representation of data. Reducing many bits of data to sub-groups. Classifying data into sub-groups.	2
6. Planning	Identifying variables that are relevant to a given problem. Identifying the dependent variable in an investigation. Identifying the variables that may affect the dependent variable in an investigation. Identifying the independent variable to be manipulated in an investigation. Identifying procedures for manipulating the independent variable in an investigation. Identifying procedures for controlling variables in an investigation. Identifying methods of measuring the dependent variable in an investigation. Identifying variables to label the axes of a graph or to be the headings on a table.	3

7.	Generalizing	Comparing data from an investigation. Identifying data that support an hypothesis. Interpolating between or extrapolating beyond data points in tables or graphs. Using data to construct an inference. Using data to construct an hypothesis. Justifying an explanation or a decision.	3
8.	Non-Cognitive	Non-cognitive behaviors that are goal-directed. e.g., collecting items of equipment. Assembling apparatus.	0
9.	Off-Task	Behaviors that are not goal-directed. e.g., eading a book while the teacher is explaining how to solve a problem.	0

Table 2

Generalizability Coefficients for
Student Engagement Data

Engagement Category	Generalizability Coefficient
Total Engagement	.92
Off-Task	.92
Attending	.91
Recalling	.57
Collecting	.89
Comprehending	.70
Quantifying	.25
Planning	.31
Generalizing	.66
Non-Cognitive	.36

Table 3

Descriptive Statistics on Wait-Time and Questioning Quality for Each Feedback Group

	Mean	Standard Deviation
Group 1 (Wait-time and Questioning)		
Wait-Time	3.97	0.24
Cognitive Level of Questioning	2.11	0.21
Questioning Clarity	1.79	0.04
Questioning Relevance	1.64	0.13
Group 2 (Wait-Time Only)		
Wait-Time	2.35	0.51
Cognitive Level of Questioning	2.01	0.35
Questioning Clarity	1.68	0.20
Questioning Relevance	1.53	0.32
Group 3 (Questioning Only)		
Wait-Time	1.22	0.31
Cognitive Level of Questioning	2.05	0.46
Questioning Clarity	1.77	0.17
Questioning Relevance	1.59	0.21
Group 4 (Placebo)		
Wait-Time	1.07	0.09
Cognitive Level of Questioning	1.65	0.30
Questioning Clarity	1.69	0.26
Questioning Relevance	1.50	0.32

Table 4

Posterior Probabilities of Group Membership Based on Discriminant Analysis of Teacher Wait-Time and Quality of Questioning

Teacher	Treatment Group*	Posterior Probability of Group Membership			
		1	2	3	4
1	1	1.00	.00	.00	.00
2	4	.00	.00	.19	.81
3	3	.00	.00	.16	.84
4	4	.00	.00	.27	.73
5	2	.00	1.00	.00	.00
6	1	1.00	.00	.00	.00
7	1	1.00	.00	.00	.00
8	3	.00	.00	.97	.03
9	1	1.00	.00	.00	.00
10	2	.00	1.00	.00	.00
11	4	.00	.00	.11	.89
12	2	.00	1.00	.00	.00
13	3	.00	.00	.94	.06

*Group 1: extended wait-time; high questioning quality;
Group 2: extended wait-time; normal questioning quality;
Group 3: normal wait-time; high questioning quality;
Group 4: normal wait-time; normal questioning quality.

Table 5

Descriptive Data for Independent and Dependent Variables

Variable	N	Possible Score	Mean	Standard Deviation
Wait-Time	13	No Limit	2.29	1.29
Cognitive Level of Questioning	13	3	1.97	0.34
Questioning Clarity	13	2	1.74	0.16
Questioning Relevance	13	2	1.57	0.22
Formal Reasoning	303	10	1.14	1.40
Locus of Control	310	33	24.30	3.69
Attending	158	100	33.12	14.97
Generalizing	158	100	1.10	1.51
Summative Process Skill Achievement	308	24	8.73	4.45
Process Skill Retention	286	24	9.53	4.74

Table 6

Relationships of Teacher and Student Variables to Integrated Science Process Achievement

Variable	Mean Summative Achievement	Mean Retention	Summative Achievement	Retention
Teacher Wait-Time	0.69** (n=13)	0.60* (n=13)	0.26*** (n=299)	0.19** (n=278)
Cognitive Level of Questioning	0.46 † (n=13)	0.39 † (n=13)	0.17** (n=299)	0.13* (n=278)
Questioning Relevance	0.17 (n=13)	0.13 (n=13)	0.05 (n=299)	0.04 (n=278)
Questioning Clarity	0.15 (n=13)	0.04 (n=13)	0.05 (n=299)	0.00 (n=278)
Formal Reasoning	0.85*** (n=13)	0.78*** (n=13)	0.57*** (n=282	0.56*** (n=257)
Locus of Control	0.27 (n=13)	0.15 (n=13)	0.04 (n=282)	0.06 (n=258)
Attending	0.58* (n=13)	0.54* (n=13)	0.34*** (n=151)	0.29*** (n=140)
Generalizing	0.13 (n=13)	0.10 (n=13)	0.38*** (n=151)	0.38*** (n=140)

†$p < .10$ *$p < .05$ **$p < .01$ ***$p < .001$

Table 7

Multiple Regression Analysis of Process Skill Achievement on Teacher Wait-Time, Categories of Student Engagement and Formal Reasoning Ability

Source	ΔR^2	B	df	Sum of Squares	F	P
Dependent Variable: Summative Achievement						
Wait-Time	.09	0.97	1	199.38	16.32	.000
Formal Reasoning Ability	.26	1.22	1	509.71	41.72	.000
Generalizing	.05	0.57	1	90.13	7.38	.007
Attending	.02	0.04	1	51.75	4.24	.041
Error			141	1722.70		
R-Square: 0.42						
Dependent Variable: Retention						
Wait-Time	0.03	0.68	1	94.74	6.86	0.010
Formal Reasoning Ability	0.38	1.68	1	940.24	68.04	0.000
Generalizing	0.05	0.76	1	167.39	12.11	0.001
Error			132	1824.10		
R-Square: 0.46						

Table 8

Multiple Regression Analysis of Mean Process Skill Achievement on Teacher Wait-Time, Student Attending, Formal Reasoning Ability and Locus of Control

Scource	ΔR^2	B	df	Sum of Squares	F	P
Dependent Variable: Summative Achievement						
Wait-Time	0.19	0.60	1	5.99	37.95	0.000
Attending	0.04	0.04	1	1.75	11.12	0.010
Formal Reasoning	0.72	2.71	1	15.30	96.94	0.000
Locus of Control	0.02	0.31	1	1.00	6.36	0.036
Error			8	1.26		
R-Square: 0.97						
Dependent Variable: Retention						
Wait-Time	0.16	0.60	1	6.55	6.19	0.032
Formal Reasoning	0.60	2.69	1	16.19	15.28	0.003
Error			10	10.59		
R-Square: 0.76						